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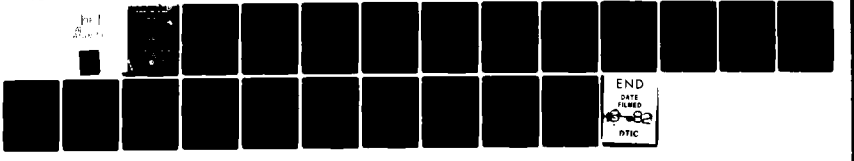

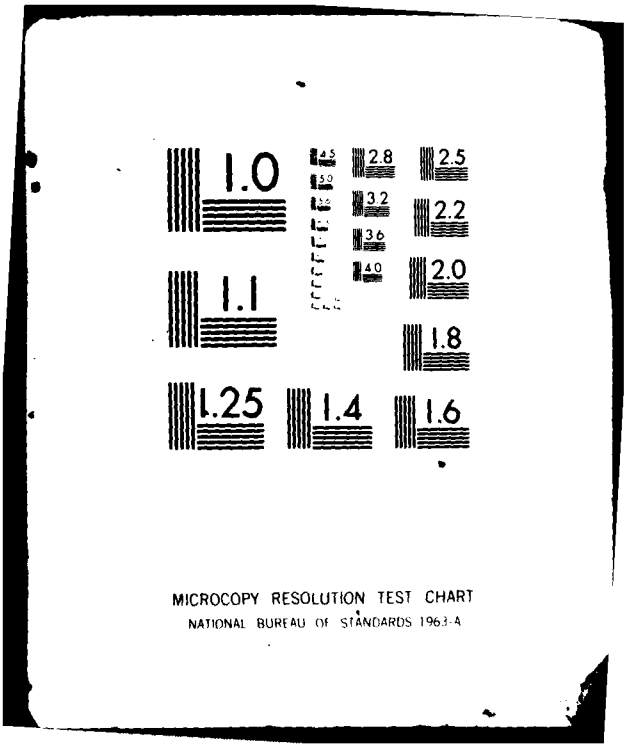
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by

Kenneth J. Arrow

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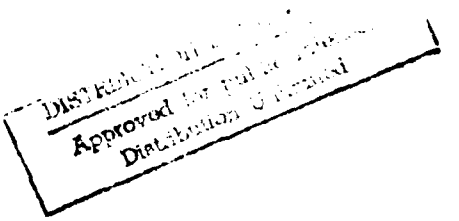

RISK PERCEPTION IN PSYCHOLOGY AND ECONOMICS*

by

Kenneth J. Arrow

The concept of rationality has been basic to most economic analysis Its content has been successively refined over the generations. As applied to the static world of certainty, it has turned out to be a weak hypothesis, not easily refuted and therefore not very useful as an explanation, though not literally a tautology. But recent decades have seen the development of stronger versions applied to a world in which time and uncertainty are real. Among its most important manifestations have been criteria for consistency in allocation over time, the expected-utility hypothesis of behavior under uncertainty, and what may be termed the Bayesian hypothesis for learning, that is the consistent use of conditional probabilities for changing beliefs on the basis of new information. These hypotheses have been used widely in offering explanations of empirically-observed behavior, though, as not infrequently in economics, the theoretical development has gone much further than the empirical implementation. These hypotheses have also been used increasingly in normative analysis a component of benefit-cost studies (therefore frequently referred to benefit-risk studies). The value of reducing mortality rates from diseases, for example, has been

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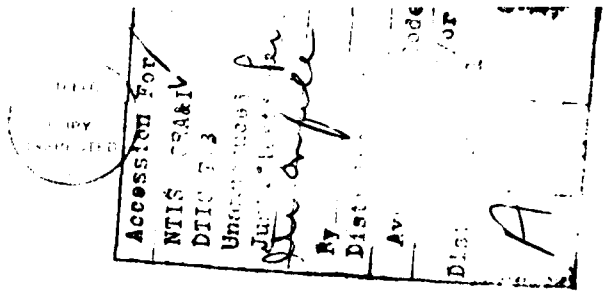
studied by assuming that choice of occupations is made inter alia by comparing wage differences with mortality differences (Thaler and Rosen [1976], Viscusi [1979]).

Hypotheses of rationalilty have been under attack for empirical falsity almost as long as they have been employed in economics. Thorstein Veblen long ago had some choice scarcastic passages about the extraordinary calculating abilities imputed to the average individual in his or her daily economic life by economists. More recently, Herbert Simon and his colleagues have produced much evidence of the difficulties of human beings in arriving at rational choices even in rather simple contexts (for a survey, see Simon [1979]).

The rationality or irrationality of choice has become a leading interest of the branch of psychology called, "cognitive psychology." This field of inquiry studies the capacity of human beings for perception and judgment. In the last twenty years, it has become a major field of psychological research, in contrast to earlier work which tended to emphasize either the role of emotions or mechanistic models for learning. In good measure, the expected-utility hypothesis provided an important starting-point for these studies, in the sense that it provided a refutable hypothesis and indeed one for which the testing of implications was rather straightforward. The economist Jacob Marschak was a major link between the formal developments of John von Neumann and Oskar Morgenstern [1947, Appendix, pp. 617-632], which had such great influence on economic theory, and the experimental work of the psychologists (see the papers reprinted in [1974, Volume I]). The earliest



experiment testing the expected-utility hypothesis seems to be that of Mosteller and Nogee [1951]; for a particularly fine study, see Davidson, Suppes, and Siegel [1957]. Herbert Simon's exploitation of the analogy between information processing in computers and that in human beings has also been very influential.

Recently, the controversy over nuclear power and its effects has sharpened interest in the way individuals form risk judgments and act on them. In particular, it has proved very difficult to reconcile changes in public opinion attendant on new events with Bayesian learning models in any form. There has been renewed testing of expected-utility theory; one striking result has been the series of stunning experiments on the so-called "preference reversal" phenomenon by Lichtenstein and Slovic [1971]. The subject is offered the choice between a pair of gambles. He or she is also asked to name, for each gamble, what is the certainty equivalent, i.e., the amount of money payment for certain which is indifferent to having the gamble. In many cases, the preferred gamble is found to have a lower certainty equivalent. This is a flat contradiction to transitivity in a fairly straightforward way. More recently Grether and Plott [1979] have replicated the experiments; they found themselves unable to develop any explanation consistent with the usual postulates of rationality.

A striking real life situation has given grounds for doubt as to the validity of the expected utility hypothesis. Since 1969, the United States government has offered flood insurance at rates which are well below their actuarial value. The intention was to relieve the pressure

for the government to offer relief when floods occurred. Under the usual hypothesis of risk aversion, any individual should certainly be willing to take a favorable bet, even more because it offsets an otherwise fluctuating income. Yet until the government increased the pressure by various incentives, very few took out this insurance. A careful study by Kunreuther [1978] failed to uncover any reason consistent with the usual explanations of economic rationality. The main distinguishing characteristic of those who took out flood insurance was acquaintance with others who took out insurance. This might be taken as an explanation in terms of information costs, but the information seems so easy to acquire and the stakes so large that this hypothesis hardly seems tenable.

Experiments and very special forms of insurance might be regarded as exceptions to an hypothesis which has turned out to be useful in more central features of economic life. Securities and futures markets might be taken as better exemplars. I have followed some of the research in these fields as someone interested in the extension of general equilibrium theory to transactions over time and under conditions of uncertainty. In these fields, there have been rich theoretical developments and equally rich empirical studies. The two types of research have not directly followed on each other, but there has certainly been a strong resonance between them. There are many aspects of the literature which bear strongly on rational behavior and on the rationality of the allocations brought about by these markets, for example, studies of the extent

to which the market price fully reflects all the information available to those in the market. But I wish here to concentrate on the rational behavior of the participants.

One standard implication of rationality which has been drawn repeatedly in current research, both empirical and theoretical, is that the price of a security or futures contract at any moment is an unbiased predictor of the price at a future moment, as adjusted for discounting and, possibly, uncertainty. This implies that the price change from the present to the future is uncorrelated with current price. This, it is argued, is a rationality condition, but it is one based on rational learning from experience. For if it were not true, the individual observing the correlation could use the information to forecast the price change and therefore increase his or her wealth.

This argument presupposes that full use of available information, in this case an observed correlation presumably derived from past experience, is an aspect of rationality. It is assumed, then, that the rational individual will recognize any correlation to be found in the data.

Stewart's [1949] study of the grain futures market brought some rather discouraging evidence on this assertion. Stewart divided the participants in the market into three categories: large hedgers, primarily millers; professional speculators; and non-professional speculators, typically small. The first group lost, as was to be expected; they were in effect buying insurance, and their behavior was compatible with rational risk aversion. The second group made money; this was to

be expected if only because they could not have survived otherwise. But the third group lost, especially surprising since they should be able to share with the professionals in receiving the net payments of the hedgers. In fact, the third group would have done better if, each time they decided to enter the market for a fixed commitment, they flipped a coin to determine whether to go long or short.

This observation certainly suggests an inability to recognize a rather simple empirical regularity, namely that outside speculators typically lose. Why did they enter the market at all?

Stewart's data, incidentally, were drawn from direct examination of customers' accounts, rather than indirect inferences calculated from market prices. To the best of my knowledge, his study has not been replicated and perhaps could not be with present privacy restrictions.

In the securities and futures markets, there are typically arbitrage possibilities. That is, there are a set of connected markets which provide substitute outlets for purchase or sale. Thus, ultimately a futures contract can be compared with a spot position; a long-term bond is an alternative to a planned sequence of investments in short-term notes, or a short-term note is an alternative to purchase and planned future sale of a long-term bond; stock purchases and sales can be arbitraged with both bond and note transactions and with future dividend payments by the firms. Since the holder is presumed to be interested solely in the money income (certan or uncertain) and not in the instrument from which it is derived, rationality has strong implications for the prices at which these instruments can sell. In the case

of bonds, for example, under conditions of certainty about future short-term interests rates, the long-term interest rate must be effectively an average of them. More generally, the possibilities of arbitrage between long- and short-term interest-bearing securities gives rise to strong implications for the whole term structure of interest rates. But these implications are not always borne out in reality. Many years ago, Macaulay [1938, pp. 29-32] examined simultaneous offers of bonds of varying maturities by the City of Detroit and by the New York Central Railroad and computed the implicit forecasts of one-year interest rates. Both series were quite irregular and differed sharply from each other as to pattern as well as level. He concluded that it would be difficult indeed to believe that the yields were the result of any deliberate forecasts.

Recently there has been a profiferation of new futures markets, mostly on financial instruments--Treasury bills, foreign exchange, and mortgage rates. It was expected that they would increase the efficiency of resource allocation, in particular because rational behavior on the part of participants would pool the information available and cause a futures price to be a best forecast, relative to the information available to the market. There has been considerable disappointment. Cagan [1981, pp. 170-172], quoting a large number of studies, holds that the futures price is no more accurate as a predictor of the future spot price than is a simple extrapolation from the current spot price. This, by itself, might mean only that there is no private information, that indeed all the information available at the present time is public

knowledge and already reflected in the current spot price. But then, since there is little knowledge about the future, there is also little change in that knowledge from one day to the next. Yet prices on these financial futures markets are highly volatile. Indeed, this is an impression which many students of these markets and practitioners in them seem to have.

To put the matter slightly differently, when participants in the market behave rationally, prices should change only when there is new information. The change in price from today to a future date, say one or two years off, will be the sum of a large number of daily changes, each reflecting new information as of that day. Rationally, it is clear from this that the change in any one day should be small, since it is merely one small piece of information among many. Hence, it seems intuitively clear that daily variations in the futures and securities markets are excessive relative to the daily changes in information.

Indeed, probability theory supplies necessary relations among the variances of prices at different times or of prices in different markets related by arbitrage possibililties. Consider the simple case of a security or futures contract which is valued today only for the purpose of selling tomorrow. If the market is efficient, then the price today is, as previously noted, the expected value of the future price. Both present and future prices are random variables. Then it is easy to see that the variance of today's price must be less than that of the future

price, since by the unbiasedness hypothesis the future price is the sum of today's price and the price difference, the latter being a random variable with mean zero uncorrelated with today's price.

There have been several studies suggesting that when tests of this general type applied to arbitrage situations, the proposed inequalilties are violated. Especially noteworthy are Shiller's [1979, 1981] studies of the bond and stock markets. For example, in the bond market, the variability of long-term interest rates is too great to be explained as resulting from changing rational anticipations of future short-term rates.

I suggest that these failures of the rationality hypothesis are in fact compatible with some of the specific observations of cognitive psychologists. I am drawing especially on the work of Tversky and Kahneman [1974, 1981]. They and others have identified several heuristic devices by which individuals form cognitive judgements and note that, while each has useful properties, each can also lead to biases in judgement.

One is the <u>representativeness</u> heuristic. The individual judges the likelihood of a future event by the similarity of the <u>present</u> evidence to it. There is a tendency to ignore both prior information, what the Bayesian would call probabililties, and the quality of the present evidence, for example, the size of the sample used as present evidence. Let me illustrate by quoting an experiment. "Subjects were presented with several paragraphs, each describing the performance of a student teacher during a particular practice lesson. Some subjects were

asked to evaluate the quality of the lesson. Others were asked to predict the standing of each student teacher five years after the practice lesson. The judgements under the two conditions were identical."

This typifies very precisely the excessive reaction to current information which seems to characterize all the securities and futures markets. It is a plausible hypothesis that individuals are unable to recognize that there will be many surprises in the future; in short, as much other evidence tends to confirm, there is a tendency to underestimate uncertainties. In the case of the student teacher, clearly there are many grounds for uncertainty in projecting the quality of one lesson into a forecast of performance five years hence: even in the present, the student teacher undoubtedly varies in performance from one time to the next, so that the one lesson may actually not be good evidence for present performance; and certainly the student teacher's performance will change in unpredictable ways under the influence of five years' maturity and experience. The best point forecast may well be the mean performance of all teachers, perhaps modified very slightly in the direction of the quality of the single lesson, just as the current weather is useless in improving on the statistical normal in predicting weather ten days hence.

The business world's concern about profit and loss statements reflects its awareness that the stockholding public uses the representativeness heuristic. There are frequently some choices as to how to represent gains and losses, especially as to their timing. The alternatives have no bearing on the true value of the firm and therefore should

have no bearing on the value of the firm's stock; but in fact they are seriously explored with regard to the effect of the profit and loss statement on stock prices. The recent liberalization of depreciation allowances created a dilemma for some firms; to receive the tax benefits, it was necessary to report larger depreciation and therefore reduce reported profits or, in some cases, turn them into losses. Even though there was by any standards a clear net gain to the firms, some of them were by no means happy with the change.

The experiments cited also have direct evidence on the insensitivity of judgements to sample size. This is true among professionally trained groups as well as laymen. Indeed, the use among all statistical research workers, including econometricians, of a fixed level of significance regardless of sample size reflects this bias, even though it has been understood since the work of Neyman and E. S. Pearson some forty-five years ago that optimal statistical testing of hypotheses should depend on a balancing of Type I and Type II errors.

Incidentally, the apparent inability to recognize the importance of sample size is again a contradiction to the implication of efficient markets and rational expectations theory, noted above, that economic agents will discover any profitable relation. The unreliability of small samples is demonstrated in any indivildual's experience; but we are apparently not programmed to group these instances appropriately and so do not make the general inference.

The drawing of inferences depends then on preconceptions, which may be true or false. The cognitive psychologists refer to the

"framing" of questions, the effect of the way they are formulated on the answers. A fundamental element of rationality, so elementary that we hardly notice it, is, in logicians' language, its extensionality. The chosen element depends on the opportunity set from which the choice is to be made, independently of how that set is described. To take a familiar example, consider the consumer's budget set. It is defined by prices and income. Suppose income and all prices were doubled. Clearly, the set of commodity bundles available for purchase is unchanged. Economists confidently use that fact to argue that the chosen bundle is unchanged, so that consumer demand functions are homogeneous of degree zero in prices and income. But the description of the budget set, in terms of prices and income, has altered. It is an axiom that the change in desription leaves the decision unaltered.

The cognitive psychologists deny that choice is in fact extensional; the framing of the question affects the answer. Let me draw a dramatic illustration from some unpublished work on choice of medical therapy by McNeill, Pauker, Sox, and Tversky [1981]. McNeill and some of her colleagues have had a program, which economists should applaud, of introducing the patients' values into medical decision-making. In this study, the comparison was being made between two therapies, surgery and radiotheraphy, for the treatment of certain forms of cancer. A therapy defines a set of probabilities of survival after varying lengths of time. In general, surgery has a distinct risk of mortality during the operation but a better survival rate thereafter. Different groups of individuals, including a group of physicians, were presented with the

probabilities of survival during treatment, for one year, and for five years for each of the two therapies. With these data, 84% of the physicians preferred surgery, 16% radiation therapy. Then another group was presented with the same data expressed differently: the probabilities of dying at each stage were given instead of the probabilities of survival. At each stage, the probabililty of dying is, of course, merely 1 minus the probability of survival, so that the two formulations are not merely logically equivalent but can be transformed into each other by a trivial calculation. Yet the proportion of physicians choosing surgery over radiation therapy dropped from 84% to 50%.

This experiment suggests the possibility that the implications of information in the market may change with alternative frames of reference, which may themselves change because of all sorts of outside and irrelevant events. In the modern era of high technology, a "breakthrough" by a firm may enhance estimates of its prospects, even among sophisticated investors, well beyond any objective measure of possible profits. The extraordinary prices paid for stock in new firms planning to use recombinant DNA technologies are surely due to the framing of the prospects in terms of technological possibilities rather than the profit perspectives for the firm.

Any argument seeking to establish the presence of irrational economic behavior always meets a standard counterargument: if most agents are irrational, then a rational individual can make a lot of money; eventually, therefore, the rational individuals will take over all the wealth. Hence, rational behavior will be the effective norm.

There are two rebuttals to the counterargument: (1) Not all arbitrage possibilities exist. For example, corporate profits, even though down, are very distinctly positive in real terms, after all necessary adjustments, including taxes. Yet there seems no way by which the average investor in corporate sescurities can get a positive real rate of return. (2) More important, if everyone else is "irrational," it by no means follows that one can make money by being rational, at least in the short run. With discounting, even eventual success may not be worthwhile. Consider for example a firm that engages in research and development which depresses the current profit and loss statement. Irrational investors look only at this information, and therefore the price of the stock is below the expected value of future dividends based on the profitable outcomes of the research and development. In a perfectly working market with rational individuals, stock prices would gradually rise as the realization date approaches, but prices in the actual market would be constant. A rational investor would understand the future value of the stocks, but he or she could not realize any part of this gain during the gestation period. While the rational investor may get rewarded eventually if the stock is held long enough, he or she is losing liquidity during an intervening period which may be long. Hence, the demand for the stock even by the rational buyers will be depressed. As Keynes argued long ago, the value of a security depends in good measure on other people's opinions.

I hope to have made a case for the proposition that an important class of intertemporal markets shows systematic deviations from individual rational behavior and that these deviations are consonant with evidence from very different sources collected by psychologists.

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